CHAPTER 7

SURVEILLANCE SYSTEM COST ESTIMATES

The previous chapters investigated the existing and emerging technologies. Their abilities and deficiencies were reviewed and the best technologies were selected for the conceptual design. In the conceptual design, the selected technologies were placed in the appropriate designs for urban and rural freeways and arterials. This chapter takes the process to the logical conclusion of computing the estimated costs for each of the conceptual designs. It is the intent of this chapter to provide an understanding of how the system cost estimate and concurrent spreadsheet were developed. It should be noted that the Study Team has developed the spreadsheet as a deliverable to the Coalition with the intent that it be used as a tool by the member agencies to calculate the system costs which corresponds with their particular design. The cost spreadsheet contains all unit cost information and inputs for sensor selection or spacing which can be easily changed to suit the user' s scenarios and assumptions.

Because of the many possible events (e.g., new technologies, funding changes) that can affect the deployment of a Corridor-wide surveillance system, the methodology used in developing the surveillance system cost estimates was emphasized. Accordingly, a variety of considerations necessary for making the cost estimates at the component level and the system levels were examined. These considerations form a basis for the cost estimate approach, and are described in section 7.1.

In section 7.2, the unit costs of the various elements of the surveillance system are provided. Since advances in technologies will affect these unit costs as well as their availability (in some cases), it is important to explicitly state the assumptions used in producing the estimates. These assumptions are provided along with the cost estimate values.

To help document the cost data and generate the system costs, a spreadsheet was developed. A brief description of the spreadsheet is contained in section 7.3. The spreadsheet permits the analysis of different scenarios using different surveillance and incident detection elements. The user can also alter the number of miles of roadway of any roadway section, or change the number of local TMCs.

Finally, section 7.4 summarizes the preliminary system cost estimate results using this spread-sheet. It also provides a description of the assumptions used in estimating the quantity of surveillance equipment. A typical roadway section of 10 miles was selected as the unit length to estimate the expected costs of installing and operating the surveillance system elements as described in Chapter 6 of this report. Both the estimated installation costs, and the operating and maintenance costs were related to the typical 10-mile section. The Study Team is aware that each agency will have unique roadway sections with different surveillance system requirements; however, in order to develop the system cost estimate, is was necessary to make general assumptions regarding roadway geometry and sensor spacing. Thus, these assumptions should not be taken as recommendations.

7.1 BASIS FOR COST ESTIMATES

The specific objectives of the I-95 Corridor Coalition are closely associated with the various user services defined in the National ITS Program Plan. The information needs related to the specific objectives within each of these user services may be satisfied by a number of different technologies, each with different operational characteristics. Thus, the deployment of a surveillance technology and its associated cost estimates require the detailed consideration of the system’ s specific functional and operational objectives (e.g., detect an incident within a specified time of its occurrence) as well as the operational environment in which the technology is to be deployed (e.g., urban freeway tunnel). This process is critical to the development of an appropriate deployment plan and provides a basis for the discernment of any problematic deployment considerations.

7.1.1 Corridor Objectives

The I-95 Corridor Coalition’ s surveillance objectives were initially established in the Task 1 of this project and described in detail in Chapter 2 of this report. Coalition’ s member agencies were surveyed to determine their objectives for the Corridor as they pertain to the implementation of a surveillance system. The results of the survey show the relative importance of the Coalition’ s objectives for the surveillance system:

1. Incident Management.

2. Traffic Control.

3. Intermodal/Multimodal Operations.

4. Traveler Information Services.

5. Planning Database.

6. Travel Demand Management.

7. Traffic Law and Regulation Enforcement.

It is important to note that incident management, as it is defined herein, encompasses snow- and weather-related emergency management, which was identified separately in Chapter 2.

7.1.2 Limiting Assumptions

User Services

The Coalition' s objectives are met by various User Services defined in the U.S. DOT' s IVHS User Service Requirements Document. The surveillance system information requirements associated with each of the User Services are fully addressed by the Incident Management and Traffic Control User Services. That is, the other user services, such as Travel Demand Management and Traveler Information Services, utilize the surveillance information collected by the Incident Management and Traffic Control systems for their operations. Hence, this report focuses on the surveillance system deployment strategies associated with Incident Management and Traffic Control, and the technologies, which provide the required data for these user services. Each of the Coalition' s objectives and its associated User Services, are described in Chapter 2.

Road Types

There are a very large number of roadway miles in the Corridor, and each roadway has its own particular characteristics that define the deployment issues associated with that roadway. For the purposes of this report, it is impossible to consider each roadway individually; rather, an attempt has been made to define a set of generic roadway types for which the deployment issues will be analyzed. This will enable each member agency to classify their roadways with one of the generic roadway types described below, thereby allowing them to infer the deployment issues for their jurisdiction.

The main factors associated with roadway classification include:

+ Roadway access control.
+ Roadway volumes/congestion.
+ Traffic controls.

Based on these factors, it is possible to develop the following set of generic roadway types:

+ Urban Freeway. The urban freeway has the following characteristics:
  - It is a controlled access facility.
  - It has relatively closely spaced on- and off-ramps (e.g., 0.5 to 1.0 mile spacing).
  - It has high demands, which approach or exceed capacity during peak periods.
  - It has no mainline traffic controls.
+ Urban Arterial. The urban arterial has the following characteristics:
  - It has no access controls.
  - It has relatively short block lengths (less than 0.5 miles).
  - All major intersections are fully signalized.
  - It has high demands, which approach or exceed the capacity of the signalized intersections during peak periods.
+ Rural Freeway. The rural freeway has the following characteristics:
  - It is a controlled access facility.
  - It has long distances between ramps (e.g., greater than 5 miles).
  - It has low demands, which usually do not approach the capacity of the facility.
  - It has no mainline traffic controls.

+ Rural Arterial. The rural arterial has the following characteristics:

  - It has no access controls.

  - It has long distances between intersections (greater than 5 miles).

  - Few, if any, of the intersections are signalized.

  - It has low traffic demands.

In addition to these roadway types, there are some unique facilities that must be considered in the deployment of surveillance systems. These include tunnels (which may preclude the use of some surveillance technologies), bridges (which may require the inclusion of additional environmental sensors), and other similar facilities.

Surveillance System Boundaries

For the purposes of preparing the cost estimate, the boundaries of the Corridor-wide surveillance system was defined as follows.

The Corridor-wide surveillance system includes:

+ The sensor units.

+ Sensor installation equipment, including foundations and conduit.

+ Cabling between the sensor and field processing units.

+ The field processing units (signal conditioner, amplifier, controller, etc.).

+ Interface to the communications system.

+ The communications system between the sensor and local communications center (including cabling and field hardware).

+ Any special software for processing surveillance sensor data at the control center, or any special hardware required for interfacing the sensor to an existing system.

The surveillance system does NOT include:

+ The traffic control center systems (except as noted above).

+ The communications system between local and regional traffic control centers.

7.1.3 Surveillance Technologies

Vehicle detection technologies form the foundation of the Corridor-wide surveillance system. The vehicle detection systems enable the collection of a range of traffic data including speed, volume, density, travel time, and in some cases, vehicle position. Control strategies, incident management procedures, and motorist information displays are selected based upon the collected data. The data is used in real time for making traffic management decisions and stored to provide a historical database for planning applications. The surveillance system can also be used to obtain information on vehicle classification, length, speed, acceleration characteristics, and hazardous materials carriers.

In order to develop the cost elements and estimates, it is first necessary to define which surveillance technologies are best suited for the Coalition' s objectives. These technologies were assessed and described in detail in Chapter 4 of this report. They are briefly summarized in this section to provide continuity. This summary focuses on the deployment and operational costs associated with those technologies which were incorporated into the conceptual design detailed in Chapter 6.

<u>Inductive Loop Detectors</u>

The most commonly used vehicle detection technology is the inductive loop. The advantages of inductive loops are their well-known performance characteristics, maturity, application flexibility, and multiple vendor availability. The disadvantages are the result of needing to embed the loops in the pavement surface, and the problems associated with pavement deterioration and freeze-thaw damage. The high replacement rate of roadway loops, and the cost of replacement in related traffic control and congestion are the primary reasons for not suggesting this type of detection.

Video Vehicle Detection Systems (VVDS)

Video Vehicle Detection Systems (VVDS) use video image processing techniques to detect vehicles and extract relevant traffic parameters. A VVDS requires field camera installations, and, depending on the particular functional requirements of the installation, may include field installation of the image processing equipment.

Depending upon the system architecture, extensive video processing of the data gathered by the WDS will be required either in the field or at a central location. Whether the processing takes place in the field or at a central location, a computer capable of handling from one to six cameras is required.

If processing is performed at a central location, the video images must be brought back to that location, thereby requiring substantial bandwidth, but the total capacity of the video processors is used. However, where existing communications capabilities allow for transmission of real-time or full-motion video, processing the images in the control center is likely to be more cost effective since fewer image processing stations are required.

Field deployment of the image processing hardware may be more cost effective where installing communications hardware and cabling to transmit real-time video back to a control center is cost prohibitive. If processing is performed in the field, video images only need to be transmitted to the processing point. Therefore, a low bandwidth, similar to that required by loop detectors, is needed. On the other hand, more video processors would be required to cover all detection stations. This will increase the system cost and may result in the processors being under-used.

Microwave Radar

Microwave radar detectors are generally of two types: continuous wave Doppler radar and Frequency Modulated Continuous Wave (FMCW) radar. The continuous wave radar detector system uses the Doppler effect to measure vehicle speed, but it does not have the ability to detect vehicle presence (stopped vehicles). The Frequency Modulated Continuous Wave (FMCW) radar detector can measure vehicle presence and has the capability to provide speed measurements, though typically not as accurately as Doppler radar.

Microwave radar detectors may be side mounted on a pole alongside the roadway, approximately 30 feet above ground level: or individual radar detectors can be mounted over each lane for more accurate data.

Microwave radar requires a substantial initial installation and calibration effort to accurately establish the detection zones. Detector performance is greatly affected by surrounding structures; therefore, a lengthy and detailed calibration process is required to ensure that vehicles are properly detected. However, once the system is calibrated, no ongoing calibration is needed.

Field data processing typically takes place locally. Communication bandwidth requirements are similar to those required by loop detectors because the data is transmitted from the receiver to the local field processor.

CCN Surveillance

The primary function of the CCTV is to verify traffic incidents. Its secondary functions may include incident detection, flow monitoring, and verification of the operation of other subsystems.

To properly control the camera' s pan/tilt position, initial and periodic calibration of the pan/tilt systems is required. Typically, three pre-determined camera positions are provided as inputs into the camera controller. Regular scheduled maintenance of the camera lens and pan, tilt, zoom servers is required.

Vehicle Probes

Vehicle probes offer real-time traffic information over a section of the roadway in contrast to "localized" data offered by point detection devices. Real-time traffic and travel time information is available from vehicle probes employing Automated Vehicle Identification (AVI) or Automated Vehicle Location (AVL) systems. The use of each of these technologies in surveillance is assessed in Chapter 4 and their suggested deployment in a conceptual design is detailed in Chapter 6. The following paragraphs highlight the cost considerations of the installations.

+ Automated Vehicle Identification, Vehicles are identified using signals emitted from the onboard transponder and recorded by a roadside reader. With the increasing use of AVI equipment for electronic toll collection in the Corridor, vehicle probe data may be acquired more easily and with minimal investments. The cost of in-vehicle installation is considered in this analysis to be borne by the vehicle owner or user, such as in the case of a bus fleet or a private trucking firm. The vehicle installation, and use, of AVI would benefit the vehicle user as well as the surveillance system.

+ Automated Vehicle Location AVL systems are computer-based vehicle tracking systems that are now used to monitor the movement of transit vehicles and trucks in real time, and in some cases the AVL systems are being used in conjunction with AVI. They are beginning to be used to monitor police cars, ambulances, and other emergency vehicles. The incident report can be automatically “stamped” by time and location, thus enhancing the effectiveness of incident detection and response. The primary advantage of collecting AVL probe data is the minimal additional capital investment required to obtain traffic surveillance information since the majority of the investment is already made for vehicle fleet management purposes.

Weigh-in-Motion (WIM)

In general, Weigh-in-Motion (WIM) sensors are installed in or on the surface of the roadway with an accompanying roadside data collection unit. The use and advantages of the several types are detailed in Chapter 4, and their suggested deployment is detailed in the conceptual designs in Chapter 6. Regular calibration of the sensor and maintenance of the system is necessary. Specific roadway installation characteristics and cost considerations are as follow:

+ Bending Plate Systems. The installation cost is relatively low compared to that of other WIM technologies. It requires a 9-inch deep pit for a lightweight frame that supports the steel plates.

+ Shallow Weigh Scales. The system consists of a steel frame supporting the load sensors and six triangular load plates. The depth of the pit is usually less than 4 inches, resulting in relatively low installation costs.

+ Deep Pit Weigh Scales. This system consists of two rectangular weighing platforms resting on a common concrete foundation. The installation cost is more than the earlier two systems due to the deeper pit required.

+ Bridge Weighing System. This system uses strain transducers clamped to the underside of the support beams of a bridge. Tape switches are placed on the road surface for the measurement of vehicle speeds. The bridge weighing system is restricted to sites with light traffic; therefore, its use in the Corridor will be minimal.

+ Capacitive Systems. A Capacitive sensor comprises two or more parallel steel plates separated by a dielectric material and encased in rubber. As a wheel passes over the sensor, the top plates deflect and cause a change in capacitance. A Capacitive system is portable and relatively simple to install.

+ Piezo-electric Axle Load Sensors. Most piezo-electric WIM sensors use a round piezo cable, though piezo film (a piezo material sandwiched between flexible rubber) is also available. In general, piezo-electric sensors are more durable than other WIM technologies.

+ Fiber-Optic Sensors. A fiber-optic sensor can be installed on the surface of the roadway, eliminating the need to dig the pavement. They are also not susceptible to electromagnetic interference and less expensive than piezo-electric technology.

Environmental Sensors

Environmental sensors provide information on road surface and air quality conditions. The use and implementation concept for environmental sensors is detailed earlier in Chapters 4 and 6.

Typically, environmental sensors require little maintenance and calibration. Usually, these units need to be initially calibrated for local atmospheric conditions upon installation. These sensors are integrated units; therefore, data processing is performed internally. A complete weather station is recommended for this use because the installation either has the required sensors, or can process the data from remote environmental sensors for transmission to central. They can be configured to only initiate contact with the TMC during alarm conditions. This allows for the use of cellular phone links, resulting in a simple communication system requirement if a roadside communication system is not available.

Human Surveillance/Cellular Phone/Call-Boxes

This is the most common type of surveillance being performed. There are a number sources for human surveillance data as stated in Chapters 4 and 6, including:

+ Police patrol.

+ Freeway service patrol.

+ Motorists call-in via cellular phone or dedicated call boxes.

Implementation of a cellular telephone motorist service requires primarily the installation of interface equipment in the TMC. However, to encourage motorists to report traffic incidents, en route traveler information dissemination assets (e.g., signs) would be needed. Thus, it is imperative that this service be highly marketed in order to maximize its potential.

Call boxes allow motorists to call for assistance in case of an emergency. Motorist call boxes require a substantial installation cost. Dedicated hardware support, and telephone and power lines must be installed along the entire section of the roadway. Sometimes, solar powered units are employed. Call boxes should be logically placed to allow for both an acceptable motorists walking time and infrastructure cost. Call-box maintenance involves: relocating phones when necessary, replacing dedicated pipes for telephone wire when needed, telephone repair, and scheduled system status checks.

7.1.4 Technology Deployment

This section provides a rationale for surveillance technology deployment. The rationale focuses on the types of sensor technology and the required spacing between sensor stations to adequately support the two highest objectives of the Coalition; traffic incident management and traffic control. The considerations of technology types and their associated spacing intervals were made for four types of roadways: urban freeway, urban arterial, rural freeway, and rural arterial. These considerations were used in developing the system conceptual design as detailed in Chapter 6, and are briefly summarized in this section as a basis for understanding the system cost estimates.

7.1.4.1 Incident Management

Urban Freeway Operations Objectives

Incident management is critical on urban freeways and is likely the most cost-effective service relative to the four different roadway types discussed in this report. Loop detector technology has been used for incident detection for several decades; however, alternative technologies have been deployed recently, including microwave radar and VVDS.

Surveillance data required to support incident detection includes speed, occupancy, and volume. Two types of existing incident detection algorithms can accept data from these various technologies: comparative and single station. Comparative algorithms are dependent on device spacing. This spacing affects the time is takes to detect an incident. The industry standard for loop detector spacing on urban freeways is 0.5 mile, which has been used in many existing traffic management systems. Since the detection time is calculated based on traffic volume, the time to detect an incident will vary relative to each particular roadway. Therefore, it is important that each member agency consider the sensor spacing with respect to their particular roadway and traffic conditions and the required detection time. For a half-mile detector loop spacing, for example, an incident resulting in full blockage will take a maximum of 4 minutes to be detected (based upon 1660 vph). Full lane coverage is required for loops.

Single-station algorithms determine incidents for a specific station. If single stations are desired at equal spacing, the maximum time to detect between stations will be equal to the time it takes for a vehicle to travel between stations.

The surveillance equipment spacings assumed for urban freeway incident management are as shown in the conceptual system design (Chapter 6). The spacing requirements address the qualifying deployment factors for each independent technology. It is important to note that if various technologies are to be deployed as an integrated surveillance system, detector spacing will vary. For example, incident detection on an urban freeway could involve the deployment of radar detectors in conjunction with VVDS and CCTV. The sensor spacings for such situation could be 0.5 miles, 2 miles, and 3 miles for each respective technology. Since only one surveillance technology per station is needed, no radar detector is required where VVDS or CCTV is used.

Urban Arterial Operational Objectives

In general, automatic incident detection is not performed on urban arterials. The primary reason is the difficulty of developing algorithms that can discriminate between incident-related traffic conditions and the normal stop-and-go traffic associated with intersection control. Attempts have been made to develop such algorithms but to date, no effective method exists.

Incident detection and surveillance generally consist of improved detection systems at primary intersections as stated in the conceptual design of urban arterials (Chapter 6). Also, a primary method for detection of incidents on arterials will be human-based, including traffic operations personnel, emergency services personnel (e.g., police), or the general public. Of these three, the general public is likely to be the main source of incident detection reports, while the police are likely to be the main source of incident verification. Telephone reporting, including cellular reporting of incidents requires no additional field equipment: rather it requires the establishment of a quick-dial cellular phone feature for reporting incidents (such as currently exists for many freeway facilities in the corridor; e.g., the *SP program in Massachusetts or #77 in Maryland).

The one area of incident management where urban arterial surveillance equipment may be required is for the diversion of traffic around incidents. Surveillance data are needed to assess traffic conditions on alternative routes, facilitate preemptive control of traffic signals to accommodate emergency-response vehicles, or adjust traffic signal timing to increase the throughput of the alternative routes.

Rural Freeway Operational Objectives

Rural freeway operational objectives are more focused toward traveler safety than traffic congestion. To support these objectives, the surveillance systems described in Chapter 6 were used to develop the preliminary system cost estimate.

Rural Arterial Operational Objectives

Similar to urban arterials, it is not possible to perform automatic incident detection on rural arterials, but for different reasons, than on the urban arterials. On the rural arterials, flow is relatively uninterrupted but is usually too low to allow for the detection of changes in the traffic conditions.

Therefore, again, incident detection on these facilities must rely on improved detection at primary intersections and on human report.

7.1.4.2 Traffic Control

Urban Freeway Operational Objectives

Inductive loop detectors, microwave radar, VVDS and ultrasonic pulsed technologies can all be used as a means for ramp metering in an urban freeway environment. Typically, a ramp meter requires coverage for each ramp lane. These installations are described in Chapter 6.

Mainline meters, though rare, are also an option on urban freeways. Examples of the objectives of mainline meters include: (a) maximize the flow through a downstream bottleneck; and (b) provide a high level of service to all vehicles downstream of a certain point. The use of mainline metering is not included in the current cost scenarios.

Urban Arterial Operational Objectives

With respect to traffic control in urban arterial areas, surveillance is required to support signal control (including adaptive control) and route diversion. For traffic signal control, the most basic requirement is the detection of the presence of vehicles at each of the approaches to the intersection. Depending on the complexity of the signal control algorithms, there may also be requirements for the detection of the queue-length on each approach. Some systems, including adaptive signal control systems, may also require knowledge of mid-block traffic flow conditions (such as speed and volume).

For route diversion, it is important to have an understanding of the traffic conditions on the link to which traffic will be diverted. Determining overall flow conditions on an urban arterial is notoriously difficult due to the presence of signalized intersection and free access to the facility.

Nevertheless, the minimum requirements would be the knowledge of the speed and volume of the traffic and the state of the traffic signal control system, so that its effect on the flow and travel speeds can be estimated. The conceptual urban arterial design is described in Chapter 6.

7.2 COST ELEMENTS

7.2.1 Software

The TMC will include a variety of software. The software can be divided into three groups: off-the-shelf software such as word processing, proprietary software such as that for variable message signs, and customized, which primarily will be required to interface with the proprietary software and the users to integrate the different components of the system.

+ Commercial off-the-shelf (COTS) software. COTS Software (such as word processors and spreadsheets) is not very costly since the cost for developing the software is recovered by selling the product to the general public for general use. For the typical workstation, $4000 per station was estimated for off-the-shelf software.

+ Proprietary software. The cost for proprietary software, such as the software for variable message signs, will be built into the cost of the hardware. No cost estimates are provided for this type of software.

+ Customized Software. Such software is needed to integrate the different components of the system and to interface with the user. Interfacing with the user is required in that the user can interact with the system via menus and screens. To feed the input from the menus and screens to the proprietary software, a protocol interface is required with the proprietary software. Also, in a TMC setup, a database would be required and would be located on the file server for the users to access. The database engine, which is the heart of the database, would be normally purchased and not developed.

  This type of software is most expensive because the cost of developing it cannot be recovered by selling the product to the public. There are several steps in developing customized software.

  - Screens and menus design. The screens and menus will be designed for the way information would appear on the computer monitor. In general, an 8.5 x 11 page showing the layout of the screens graphically is used. Approximately a 2-month time frame would be required to have the screens and menus design in place.

- Report format design. The report format will be designed for the way the format of the printed reports would appear when printed. In general, an 8.5 x 11 page showing the layout of the report graphically is used. Approximately a 2-month time frame would be required to have the report format design in place.

- Flow Chart design. The flow chart design is to graphically show the flow of logic and data in the program. The flow charts assist in sectionalizing the program to several modules, and identify the variables used across modules. Approximately a 2-month time frame would be required to complete the flow chart design.

- Coding. This stage is the actual programming stage where the information derived from the first three stages is used. Approximately a 4-month time frame would be required to complete the coding.

- Emulation testing. During this step, the different modules are tested in an emulated environment, i.e., no real nor live data is tested. In conjunction with the emulation testing, all major problems and bugs would be fixed. Approximately a 2-month time frame would be required to complete the emulation testing.

- Live testing. At this stage, the software is placed under real condition testing. For about 5 to 6 months, constant monitoring of the software would be required. Bug fixes would be addressed immediately and corrected. Every module in the software should be tested in this stage. After the first 3 months of initial live testing, the software could be used as it is intended, while continuing with testing.

- Enhancements. Enhancements come after the software has been functional for about 6 months. Enhancements are additional items that were not identified at the beginning of the development or items that require changes due to difficulty in their functions.

7.2.2 TMC Communication System

The purpose of this section is to list which communication alternatives would serve as the communication media to carry signals to and from the field, such as for CCTV and vehicle detectors. Several alternatives would be applicable such as leased telephone lines, microwave, and fiber optics. The selection of which communication media best suits each member agency' s needs depends on their existing communication system. For the purpose of the cost estimate, all communication alternatives were included in the spreadsheet.

It should be noted that communication for local TMC to other local TMCs, to the regional TMC, and to Corridor-level information centers is handled by the Information Exchange Network Project (Project #1); therefore, it is not included here in the surveillance system cost estimate. The communication system cost estimate covers the communication network both external to and within the local TMC. For interconnection with non-surveillance field equipment such as variable message signs, a regular telephone line (DS-0) can be used in either a leased form or dial-up form. However, the cost of such a line is not included in the estimate.

Leased Telephone Line T1 Circuit

The leased Telephone Line 11 Circuit (DS-1) is a very commonly used medium. It possesses the flexibility, speed, and bandwidth. In addition, lease telephone is a very reliable communication solution in that redundancy is incorporated into the telephone company's network. A T1 circuit, operating at 1.544 Mbps, would be useful for transmitting combined data and digital video between various TMCs and between the field and the TMC. Assuming that approximately 128 cameras are used in a surveillance system, it would be possible to carry all the signals back on 42 T1 lines. With three cameras sharing one T1 line, the jittering of an image would be very noticeable when pan, tilt, and zoom signals are sent back via the T1 line. By having 2 cameras share one line, the image quality will improve: however, additional T-l lines would be required. For the purpose of this estimate, 42 T1 lines were assumed.

The estimated cost for 42 leased T1 lines is $105,000 ($2,500 per T1 line). The actual cost of a T1 line depends on the location and distance. Also, some government entities have arranged for lower rates. As an example, the monthly cost for a T1 line through Maryland from the Delaware border to Washington DC is approximately $4,000; but the State of Maryland receives a discount that reduces the cost by almost half. Therefore, the $2,500 monthly cost estimated above is an average, given that a TMC will be within a reasonable distance from the field locations.

The low initial costs and almost no maintenance costs could entice one to use this method of communications, but the monthly cost is high. This type of communications is not recommended as a permanent solution.

Microwave

Microwave is a radio-based type of communication. Its major advantage is that no physical connection is required between the receiver and the transmitter. This can translate into significant cost savings over the installation of a cable conduit network. Microwave links provide direct line in analog and digital form. Microwave transmission requires a line-of-sight path with relay towers spaced according to the frequency being used. For 2 GHz and 6 GHz, a spacing of 30 miles is typical, whereas for a 23 GHz frequency, a 10-mile spacing is typical. Since an FCC license is required, the availability of radio frequency may be limited depending on the location of use.

The initial construction cost of this type of communications is estimated at $100,000 for the 23 GHz system and $270,000 for the 6 GHz system. The difference in cost is not as great as it appears. If a 30-mile section is considered, the cost for the 23 GHz system is three times $100,000, or $300,000. The cost for the 6 GHz system is $270,000 for the same 30-mile section. Therefore, the distance between TMCs should be an important factor in considering which type of system is to be used. The microwave system is an acceptable communications system if a fiber-optic system is not available.

SONET/Fiber-optic

SONET (Synchronous Optical Network) is the ANSI standard for advanced fiber-optic transmission. SONET nodes allow for data transmission over a fiber-optic cable. The true advantage of fiber optics is virtually unlimited capacity that can easily support any type of video and data communication. In addition, fiber-optic communication is not subject to noise and corrosive effects. SONET OC-12 is the basic transmission speed of the network. This speed is equivalent to 600 Mbps.

The function of a multiplexer on a SONET node is to allow many low-speed data feeds to be combined into a single signal which can then be broken down into its original components at the intended destination. These lower speed data streams include SONET OC-3 (150 Mbps), OC-1

(50 Mbps), and T-l (1.5 Mbps). The SONET multiplexers have a transmission range of at least 25 miles: however, ultimate transmission distances are virtually unlimited, in that the signal can be totally regenerated at each node. In this regard, connection of any field component to various control centers along the fiber-optic trunk line is feasible with this technology.

The cost of a fiber-optic system can be considered in two parts, the installation of the cable, and the installation of the SONET hub equipment. The fiber-optic cable should have a life of more than 20 years; therefore, once it is installed there are no maintenance or replacement costs. The SONET hub equipment costs depend upon the type of system installed. An OC-3 system is less expensive than an OC-12 system. It is generally accepted that the installed system should have an excess bandwidth compared to the current requirements. For the communications between TMCs (which is not a part of this preliminary cost estimate), an OC-12 system is acceptable and is estimated to cost approximately $411,000. This estimated cost will change with the type and extent of the access system. The estimate included an access system that would communicate to several SONET hubs as well as another TMC.

7.2.3 Hardware

7.2.3.1 Vehicle Detectors

Operational environment and maintenance requirements are two of the most critical factors in determining the types of detectors for the system. Systems that involve cutting existing road surfaces and pavement structures (such as induction loops) can create installation and maintenance problems or compromise the structural integrity of the roadway. Technologies that do not require these modifications are termed non-intrusive installations, and minimize traffic diversion and control problems. Although many of these technologies that have been tested show promise, many have not progressed to reliable field operation. To limit system complexity, and resultant operations and maintenance costs, minimizing the number of different technologies is preferred.

<u>Inductive Loops</u>

The cost associated with loop detectors includes the loop detector and loop detector lead wire. The loop detector wire, which is placed into the pavement, has a cost of $7.20 per foot. The loop detector lead wire, which connects the loop detector cable and controller has an estimated price of $0.20 per foot. To detect vehicle speed, two loop detectors are required for each lane. Therefore, a typical section with two lanes per direction will require four speed traps, or eight loop detectors. Estimated cost for eight detectors would be $3,320. In addition, one 170E controller is required to serve these loops. A controller, which costs $15,200, should be placed in the field cabinet, and the cabinet's unit cost is $8,400. The field cabinet should be placed on a foundation, estimated at $1,100.

An overall typical section of I-95 with two lanes each direction equipped with four speed traps, a 170E controller, and a field enclosure with foundation would cost around $28,000.

Radar Detectors

This system generally contains a detector, detector mountings, a detector controller, detector controller mountings, detector standards, and a foundation. The Continuous Wave radar detector (CW) requires one detector per lane mounted on the structure or a sign bridge over the lane. Unless existing structures are used to place the detector, cost of the overhead structures could be very steep. One CW detector costs $1,400 plus a detector mounting of $500. Wide-angle modules are available, which can be mounted on the side of the roadway, often on the lighting pole. The advantage of this approach is that one detector is sufficient for each direction and additional savings of $3,000 can be achieved for each lighting pole used. This is the cheapest approach, but it does not provide lane-specific data nor accurate detection of slow-moving or stopped vehicles.

Another type of radar detector (RTMS) can scan many traveling lanes from the side-mounted position. A unit costs about $4,500 (plus $500 for the detector mounting) which is a much higher unit price then for the CW unit. A higher unit cost is offset by using one detector per direction or sometimes one unit for both directions. The RTMS system does not provide accurate short interval counts, and for longer interval count, its accuracy is about +5%. Its speed accuracy is even lower than that of the counts' accuracy.

Some of the radar detection element costs are shown in Table 7-1.

Table 7-1. Estimated Cost of Radar Detection System

Element	Cost
Detector Controller Assemblies	$7,400
Detector Controller Assembly Mountings	$500
Detector Standards (23 ft)	$1,900
Foundation	$1,100

Video Vehicle Detection System

The VVDS contains a video camera, short haul fiber-optic video transmitters, video detection assemblies, camera standards and a drilled caisson. The video detection assembly includes a video processor, software and hardware. The video processor can generally serve up to six cameras, and has a price of $35,000. Other cost elements of a VVDS are presented in Table 7-2.

Table 7-2. Estimated Cost of Video Vehicle Detection System

Element	Cost
Camera Assemblies	$10,200
Short Haul Fiber-optic Video Transmitters	$2,900
Video Detection Assemblies	$78,000
Camera Standards	$6,200
Drilled Caissons	$4,600

7.2.3.2 Closed Circuit Television

The primary role of CCTV is to verify a reported incident, evaluate its severity, and determine the appropriate response vehicles and personnel to dispatch to the incident scene. Color images provide the greatest visual information, and are the preferred choice of most traffic operations centers. However, color CCTV cameras rapidly lose their sensitivity under nighttime, or other dim lighting conditions. Black-and-white cameras, on the other hand, are available that will produce usable images even when it is too dark for a person to see. The difference in cost between a color and monochrome camera is approximately $200. Some vendors have solved this dilemma by packaging both a color camera and a black-and-white camera in the same housing. This, of course, increases the price of the assembly, but the added cost may be acceptable in some locations.

Most control center operators, who have both types of cameras at their installation, believe that color does present significant enhancements. A recent study in Colorado suggests that the best results showed a zoom of x10 color CCTV. Therefore, for this preliminary cost estimation, this type of camera is assumed to be used. The CCTV system elements are a video camera, short haul fiber-optic video transmitters, camera standards, and a drilled caisson. The element prices are shown in Table 7-3.

Table 7-3. Estimated Cost of CCTV Camera Installation

Element	Cost
Camera Assemblies	$10,200
Short Haul Fiber-optic Video Transmitters	$2,900
Camera Standards (55 ft)	$6,200
Drilled Caissons	$4,600

7.2.3.3 Weather Station

The ability to obtain weather, visibility, and roadway surface condition data, in real time, can greatly improve the safety of motorists. This is the function of a computer-assisted weather station. Through the use of weather station data, roadway thermal profile data, and specially designed computer software algorithms, it is also possible to forecast which sections of roadway are likely to freeze first. This can greatly aid work crews in scheduling, preparation, and application of deicing and traction improvement materials.

A typical roadway weather station system consists of condition and weather sensors, one or more remote processing units, a central station processor, and an operator interface. Road surface sensors provide information about pavement conditions. This sensor could be a maximum of 2500 feet away from a Remote Processing Unit (RPU). One road surface unit costs $4,000 and the number of detectors employed will be specific for each application. One RPU can serve up to four road surface and four subsurface and atmospheric sensors. The RPU with enclosure costs $16,000 and can be installed on a small or big tower. A big tower is required for wind, visibility, and precipitation sensors and costs $2,000. A smaller tower is estimated at a lower price of $1,100.

A system including a Weather Identifier and Visibility (WIVIS) sensor with approximately a 1-mile range and a precipitation classifier costs $11,000. Vendors also provide WIVIS units with improved performance, but without precipitation classifiers, at unit cost of $11,700. For precipitation sensing, two different types of sensors are available and may be bought separately from the WIVIS. The first type detects whether there is precipitation or not, and costs $2,300. The second type is a precipitation classifier costing $9,000. The WIVIS unit equipped with a precipitation classifier is assumed to be used, due to its price advantages. A wind speed and direction sensor costs $620 and a relative humidity and air temperature unit costs $2,500. The weather station requires one CPU which can serve up to 250 RPUs with a unit price of $25,000.

7.2.3.4 Ramp Metering

For the I-95 Corridor application, it is assumed that integrated ramp control will be used for the urban areas. This type of control takes into account the interdependency of a series of entrance ramps. Its primary objective is to prevent or reduce the occurrence of congestion on the freeway. Therefore, the control of each ramp in the system is based on the demand-capacity conditions for the whole system rather than on that of each individual ramp.

A significant feature of integrated ramp control is the interconnection among local ramp controllers which permits conditions at one location to affect the metering rate at other locations. Real-time metering plans are computed and updated by a central master controller, which issues metering rates to the respective local ramp controllers, based on freeway traffic information obtained from vehicle detectors throughout the system.

Ramp metering equipment includes a traffic sign, traffic sign foundation, ramp metering flashing sign, ramp metering flashing sign foundation, 170 controller, field cabinet, and field cabinet foundation. The prices of these elements are shown in Table 7-4.

Table 7-4. Estimated Cost of Ramp Metering System

Element	Cost
Traffic Signal Assemblies	$1,750
Traffic Signal Assemblies Foundation	$770
Ramp Metering Flashing Sign	$8,200
Ramp Metering Flashing Sign Foundation	$1,300
Controller 170	$11,800
Field Terminal Cabinet	$8,400
Field Terminal Cabinet Foundation	$1,100

It is desirable to use two traffic signs and two ramp signs for each site. In addition, ramp metering requires queue detection which can be accomplished with at least two loop detectors (preferably four) or an RTMS radar detector or a VVDS. Since ramp metering equipment already includes the controller and field enclosure, loop detection is the cheapest option. For an optimal operation, the most desirable option is VVDS, but with a significantly higher price.

7.2.3.5 Weigh In Motion (WIM)

There are many WIM technologies available on the market with distinct cost, measurement accuracy, and maintainability. Low-cost systems generally offer lower performance, such as bending plate. On other hand, deep pit and load-cell-based WIM technologies provide more accurate measurements and are easier to maintain, but the equipment and installation cost is much higher. Since weight measurement accuracy is important in law enforcement and toll rate determination, a load-cell WIM system seems to be the most suitable for the I-95 Corridor surveillance system. In many cases, the WIM unit is accompanied by an Automated Vehicle Classification (AVC) System. Table 7-5 shows the prices of various WIM and AVC systems made by the PAT Traffic Control Corporation. The cost estimate for the TOLIDO Load-Cell WIM system is $20,000 per lane, but the price includes only the necessary equipment. The Cost Estimate Spreadsheet uses the load cell type for calculations. Should a different type be substituted (e.g., piezo type), the spreadsheet must be rerun to reflect this change.

Table 7-5. Estimated Cost of WIM Systems

No. of Lanes	AVC System	Piezo WIM System	1-Bending Plate WIM System	2 -Bending Plate WIM System
1	$14,500	$22,606	$28,000	$33,500
2	$15,500	$27,000	$36,500	$45,000
3	$18,500	$30,300	$44,500	$58,500
4	$20,500	$34,000	$52,500	$72,500
5	$23,500	$51,500	$65,000	$96,500
6	$25.500	$56,000	$68,500	$109,500

7.2.3.6 Automated Vehicle Identification/location (AVI/AVL)

Automatic Vehicle Identification utilizes radio frequency interrogation to identity transponders or tags mounted on vehicles. Applied to Electronic Toll Collection (ETC), AVI requires many system design considerations for successful implementation. Tag reading performance is especially critical considering the tens of thousands of vehicle passes on a daily basis and millions of trips billed/debited each month for a typical toll authority. In addition to accuracy, an AVI system must be capable of properly correlating the AVI data with that of other systems such as WIM, Automated Vehicle Classification, vehicle presence detection, and automatic enforcement systems. Texas Instrument’ s TIRIS is an AVI system with an open architecture. Its vendor claims that the system’ s accuracy exceeds 99.95%, independent of traffic conditions. The estimated roadside equipment cost is in the range of $10,000 to $20,000 per lane. One different approach for AVI was used by Perceptics Corporation and Siemens. This approach is based on the license plate or character recognition technology. One-lane coverage by this type of system would cost about $30,000 (Perceptics).

Automated Vehicle Location (AVL) and Computer-Aided Dispatch (CAD) technologies may be applicable to service patrol vehicle fleet management. The probe data from such a system may be used for traffic surveillance purposes. The in-vehicle cost for CAD/AVL systems would be about $10,000 per vehicle. The cost related to the dispatcher center and mobile communications would be $200,000 to $500,000 and $1.4 million, respectively.

7.2.3.7 Call-box

An emergency phone that operates on standard phone lines or PBX systems, requires no power supply or battery backup. New technology now allows for wireless emergency phones such as cellular. Cellular type call-boxes are usually battery powered with a solar power charging system. If a call-box is mounted on an existing post, its cost with enclosure would be about $700. Additional features could be added for additional cost such as Intelli-Voice Location identifier ($80), Emergency Light/Strobe ($365), and Scream-Alert ($200).

7.2 .3 .8 Aerial Surveillance

A multi-sensor surveillance aircraft (MSSA) provides an area-wide picture of the traffic conditions along the I-95 Corridor to augment other land-based surveillance systems. The present MSSA estimated cost is in the range of $6.5 to $6.0 million with hourly operation and maintenance cost of $250 (excluding personnel because of lack of information due to the emerging technology involved). An alternative to the purchase and local operation of an aircraft is the leasing of an aerial surveillance service. The approximate cost of this service is $1,000 per hour. This cost includes the aircraft and crew, and removes the burden of aircraft purchase, operation, and maintenance from the Coalition’ s member agencies.

7.2.3.9 Closed Loop System For Traffic Signals

The Closed Loop System (CLS) is a distributed processor traffic control system with control logic distributed among three levels: local controller, on-street master, and off ice microcomputer. The CLS maintains a traffic signal system in time-of-day or traffic-responsive mode by two-way communication between the office microcomputer and the on-street master, and between the on street master and the local controller. The CLS has many features/advantages such as the following:

+ Input and revise timing and phasing from the office computer.
+ Input and revise coordination offsets, Time-of-Day functions and parameters.
+ Program special events.
+ Obtain traffic volume data from the system detectors.
+ Monitor controller and detector operation.
+ Monitor controller maintenance.
+ Utilize intersection and display features.
+ Obtain operation reports.

The software to operate the system is either firmware purchased from the equipment distributor or manufacturer, or specially developed. Communication can be achieved by a hardwired telephone line, radio, or a fiber-optic line.

The Traffic Responsive mode, which provides for traffic adaptation based upon predetermined cycle lengths and timing related to real-time volume and/or occupancy, uses data received from system detectors along the arterial or main corridor for its operations.

Usually intersection detection is accomplished by loop detectors or by radar detectors, but it could be done by VVDS, which in addition provides intersection surveillance. Generally, one VVDS is required to monitor one signalized intersection approach. Under the assumption that existing intersections are signalized, additional equipment, presented in Table 7-6, could be required.

Table 7-6. Estimated Cost of A Closed Loop Signal System Using Radar Sensors

Element	Cost
Cabinet, Type P	$7,000
Interconnect Hardware, Local	$1,700
Interconnect Hardware, Local Field Master	$6,500
Interconnect Hardware, Dial-Up Field Master	$1,600
Interconnect Hardware, Dial-Up Central	$25,000
Hardware, Field Master	$500
Hardware, Central	$600

7.2.4 TMC Hardware - Computers and Peripherals

7.2.4.1 Workstations

Six workstations for the system operation and two workstations for support such as programming, administrative, etc. are needed. These stations will be running a GUI-type environment such as windows. Also video from the cameras can be captured and displayed on the monitor. To achieve a good level of performance, the CPU and Video components have to have fast processing capabilities. A P6 CPU with a 4M VRAM video card and 20” monitor would be suitable for this operation. A 100 Mb network interface card is selected to allow a greater bandwidth for a local area network. This greater bandwidth will be needed to achieve adequate video transmission through the LAN. The 32 Mbyte system memory and the 1 Gbyte hard SCSI hard drive were selected to allow for adequate processing space and local storage. The cost for eight workstations is approximately $72,800.

7.2.4.2 Server (Video Processing and Central Database Server)

The heart of the system would be the file server processor. This system would use a 32-bit operating system, providing higher speed than a standard PC. This sewer would be equipped with another server as a “hot” standby unit, which would be able to automatically assume the function of the primary server, when needed. If the file server system fails, disruption of the entire operation will occur. The two servers will require a similar setup. The RAID unit with a hot swap is beneficial in this setup since it provides redundancy amongst the hard disks. This way, if a hard disk is lost, the system switches automatically to another drive in the set and continues operations without disruption. The cost for two servers is estimated at $228,000.

7.2.4.3 Server (Fax Server and Regional Data Interface BBS)

A fax server would be a high end PC equipped with dual P6 processors, 10 Gbyte SCSI hard disks, 64 Mbytes of memory and six fax/modems. This server would utilize a specialized software for fax broadcasting and fax retrieval (e.g., Fax broadcasting such as to send out a fax to several destinations about travel conditions on a certain route). Fax retrieval would be where the public can call a certain number and by choosing certain options via the telephone keypads, can receive a fax that can be sent to a remote fax machine detailing all construction activities along a certain route. A similar PC can be set up as a Bulletin Board System (BBS) for public and media usage. This setup would be useful where a computer user can access this BBS via his PC to retrieve information about weather conditions and roadway conditions. The cost for two severs is estimated at $35,000.

7.2.4.4 Storage System

The storage system will work as a backup and archival unit. Magnetic tapes are very slow when retrieving information. A juke box of erasable magneto optical drives using a SCSI interface allows the user to retrieve information close to the speed of a hard disk. Data, snapshots of video, even full motion video could be saved to and retrieved from the juke box. This juke box would be installed on the LAN and WAN system for other TMC access. The cost for this storage system is estimated at $60,000.

7.2.4.5 Printers

Printers are an integral part of any computer-based system since they allow for the production of hard copies of the digital data. A color printer would be useful to print color snapshots taken from the live video. This capability may be useful if a hard copy of a color picture is to be produced from a live video of a certain incident. The estimated cost for two monochrome printers and one laser color printer is $14,900.

7.2.4.6 LAN (Local Area Network)

A LAN would be required to connect the servers with the workstations, printers, and the storage system. The LAN would allow the users in the TMC to access information, view it, and print it from the individual stations. Such use would be to enter information in the fax server or the BBS for the individual workstations as an incident occurs and needs to be disseminated. The LAN proposed for the TMC would be based on 100 Mb bandwidth which is a more suitable bandwidth for video transmission. The estimated cost for a 25 node, 100 Mb LAN system is $41,500.

7.2.4.7 Multiplexer

The function of a multiplexer is to combine the signals from several sources and send it through one channel, such as the T1 line. At the other end of the T1 line, the signals will be decoded via another multiplexer and transmitted to another destination. The signals from the cameras in the field will be combined in the field multiplexer and transmitted to the TMC via a T1 line. In the TMC, another multiplexer will decode the signals coming through the T1 line. A maximum of three camera signals can be combined into one T1 line with minimal loss to the full motion video. This multiplexer can transmit the pan, tilt, and zoom signals back to the field multiplexer and then to the cameras. For this setup, it was assumed that a maximum number of 128 cameras would be used. Since a maximum of three camera signals can be transmitted through one T1 line, 42 multiplexers were priced in this cost estimate. The cost of 42, three-channel multiplexers is estimated at $294,000.

7.2.4.8 CODEC

Digital video can be produced by CODEC. The CODECs would receive or transmit video data at 384 kbps, which is considerably below “broadcast quality” but still considered acceptable for traffic monitoring. Such compressed video data produces images with approximately one-fourth the number of pixels as full motion video, and the images tend to jitter. Operational use at night could be a problem in that maximum resolution is desirable to offset the effects of low light levels. A maximum of three channels of digitized video, representing three cameras, could be combined into a single T1 by using multiplexers. With three cameras sharing one T1 line, the jittering of an image would be very noticeable when pan, tilt, and zoom signals are sent back via the T1 line. For this setup, it was assumed that the capability of displaying 18 cameras simultaneously would be optimal, therefore 18 CODEC units were used in the cost estimate. It is estimated that 18 CODEC units will cost $270,000.

7.2.4.9 Video Switch

A key component of the CCTV system is the video switch that allows any CCTV camera to be viewed on any monitor, at any location that has access to the CCTV system. A variety of switch architectures are available, from fully centralized to fully distributed. Each has its own advantages and disadvantages, and associated costs. Most CCTV systems have more cameras than monitors, with typical ratios being in the 3:1 to 10:1 range. The cost of video switches is a function of the number of switching points, which is the product of the number of camera inputs and monitor outputs. Thus, prices can increase exponentially as the size of the switch grows. For this setup, it was assumed that a total of 128 cameras will exist in the field. A video switch with 128 inputs can handle the signals from all the cameras. This video switch allows for the switching of the camera signals between a maximum of 18 screens. This capability would allow display of a different image on each of the 16 monitors on the wall screen system to monitor 16 different field locations. The video switch cost is estimated at $50,000.

7.2.4.10 Wall Screen System

A wall screen system can be useful for decision support during incident response or for public relations during tours or demonstrations. The screen wall combines 16 (374nch) video monitors into an array. This array is four monitors high and four monitors across. Electronic circuitry divides the original image into smaller parts (e.g., 16 for a 4 x 4 array) and displays each sub-image on a separate CRT. Furthermore, the image can be displayed on four screens, which allows four different images to be displayed on the whole screen wall, one image on every four screens. The four-by-four wall screen system cost is estimated at $120,000.

7.2.4.11 CCU and DACS

A Digital Access Cross-connect switch (DACS) would receive and reroute digital data stream to other TMCs. The DACS would be capable of separating the video channels and repackaging the data for broadcast to those agencies that desire to view this transmission. Without cross-connect capability at the digital level, some image quality would be lost in multiple digital-to-analog and analog-to-digital conversions, such as the CODEC operation. The proposed example is based on a 1.54 Mbps T1 circuit line. This item is estimated to cost $125,000.

7.2.4.12 TV and VCR

These units are included primarily for recording video signals and viewing the video on the TV. Such a function would be useful in capturing video signals on the spot. This also could be accomplished by saving the video as digital data on the juke box or the hard drives. However, a VCR allows for quick and immediate operations, which are not adequate for the long-term storage that the juke box offers, The 37” projection screen TV is estimated to cost $4,500, and the VCR is estimated to cost $500.

7.2.4.13 Uninterruptible Power Supply (UPS)

The UPS online function is to provide power supply for the servers in case of power interruption. The servers keep active data in its memory area. This data is flushed to the hard disks occasionally. If a loss of power is to happen, the data in the memory area will be lost. The UPS unit can keep the server powered up for approximately an hour after the power is lost without the loss of any data. During this hour, one of the following can occur, either the data will be flushed to the hard disks of the system for shut down or the power is restored temporally via an emergency power supply unit, or permanently from the utility company. A UPS system is estimated to cost $3,500.

7.2.4.14 Emergency Power Supply

An emergency power supply consists of a diesel engine and a power generator. It provides electrical power to the TMC for heating, equipment, hardware and the communication system in case of a long-term power outage during winter storms. This unit is capable of providing all the power needed to keep the TMC operational as in normal conditions. It is equipped with an auto transfer switch and auto start and shut-off. The auto transfer switch transfers the TMC load from the generator to the public system when normal power is restored. The auto start and shut-off function is to start the diesel engine upon power loss, and to turn the engine off upon power restoration. The emergency power supply, a diesel generator, is estimated to cost $45,000.

7.2.4.15 Surge Protector

Surge protectors eliminate power surges especially during lightning storms. These devices protect the equipment attached to their circuit by stopping the power surges from passing through. If a power surge is allowed to pass through to the computer system, it will cause a major shut down as the power supplies of these units as well as the systems board and other electronic devices will be damaged. Two surge protectors are estimated to cost $9,000.

7.2.5 Public Interaction

Public interaction is a means to receive data from human surveillance. This item includes contact with the TMC (Traffic Management Center) by telephone. Regardless of the type of telephone service, land lines or cellular, the input to the TMC would be via land lines from the local telephone exchange. The TMC should also have an 800 number service to encourage public input. The phone service from the TMC to the public, to confirm incident information and request information from other sources such as police, could be handled by land lines or cellular phone.

The input system in the TMC would be a standard PBX unit and an 800 number. This PBX unit would terminate the incoming trunk lines and redistribute the incoming calls to the appropriate person or persons in the TMC. It is estimated that the PBX would need to distribute calls to approximately 20 or fewer stations in the TMC. Human surveillance can pose a problem for the TMC personnel because several calls could be received for each incident. The addition of an automated answering system would greatly improve the ability of the TMC personnel to answer multiple incoming calls. The cost of a small PBX for the TMC is estimated at $15,000 and the cost of an automated answering system (VMX) is approximately $40,000. These costs represent the lower end of the possible costs. The actual cost of these components depend upon the number of stations serviced, in general the PBX costs usually range between $10,000 and $20,000, and VMX costs could range from $20,000 to $100,000. The yearly cost of operating the telephone service, including an 800 number, is included in the operating and maintenance costs for the TMC, stated elsewhere in this report. Therefore, the only cost related to public interaction is the initial equipment cost, estimated at $55,000.

7.2.6 Personnel - Staffing Requirements

For the Traffic Surveillance System to operate effectively, the TMC must be fully staffed and effectively operated. The TMC is expected to be fully staffed and operational for two shifts per day, 5 days per week. An additional operator may monitor the system during off-shift times such as nights and weekends. Each regular shift will include an Engineer or Supervisor and two system operators, and may include one technician (who may otherwise be on-call). In addition, one shift per day will include the TMC Director, and the Communications Specialist and Software Programmer need to be available. There may also be support personnel who would not necessarily need to be full-time TMC staff members. All TMC personnel must possess excellent communications skills, be alert, computer literate, and have a solid working knowledge of the geographic area. In addition, each staff member should be adequately trained to handle two jobs, with the supervisor capable of performing each of the other functions, at least in a basic capacity. These personnel could also be used for incident response functions in the TMC.

It should be noted that the size of the system will affect the staffing requirements. The size of the staff considered here is thought to be sufficient based upon the assumed size of the local systems. As a local system is increased, the number of System Operators and Support Personnel will increase. The supervisors and technical personnel will not increase as quickly. The size of the staff listed is the minimum size for a two shift operation for an initial system. Table 7-7 shows a summary of the estimated TMC staffing needs.

The Director will be responsible for overall day-to-day operations, staffing, budget and future planning of the Traffic Management Center. This position will require a thorough knowledge of traffic engineering theory and practices. The Director should have a degree in either civil engineering (traffic) or electrical engineering and have at least some experience in the area of traffic, preferably in a supervisory capacity.

Table 7-7. Summary of Estimated TMC Staffing Needs

Personnel	Shift 1	Shift 2	Total
Director	1		1
Communications Specialist	1		1
Software Programmer	1		1
Engineer/Supervisor	1	1	2
System Operator	2	2	4
Technician	1	1	2
Support Personnel	1	1	2
Total			13

The Engineer or Supervisor will be responsible for providing overall technical direction during their respective shifts and report directly to the TMC Director. They will make decisions to implement various traffic management strategies such as diversion planning during incidents, and variable message sign and highway advisory radio operation. Other responsibilities would include evaluation of system effectiveness, development of new strategies, and coordination notification of appropriate agencies and personnel, when required. They further will be required to prepare reports on the operations and to train staff as needed. The Engineer or Supervisor should have a working knowledge of all aspects of the system, and it is helpful (but not mandatory) that they be a civil or electrical engineering graduate with a minimum of 2 years of experience.

The Operators will monitor the control panels, analyze data, advise the Engineer or Supervisor of system failures, execute system directions, report system status to relief operators, recommend nonstandard actions to the supervisor, and assist in report preparation. Various TMCs have found that college students can make very good operators.

The following positions may or may not be full-time TMC employees. They are basically support personnel, and the amount of time that the TMC requires their expertise will vary. As a result, they may only work part time, on an as-needed basis, at the TMC.

The Software Programmer will be responsible for maintaining existing software and installing new software or enhancements. Programs will be written to extract data for specific reports as needed. The programmer will also provide other software support services and administrative assistance. A minimum of 5 years of experience in programming should be required for this position. Ideally, at least some of this experience should be in programming of traffic management related software.

The Communications Specialist will be responsible for troubleshooting the communications system and debugging identified problems. The specialist will also be responsible for coordinating maintenance repairs on the system equipment. This position requires a minimum of 5 years of experience in the field as well as extensive training and troubleshooting skills in electronics. The specialist should also possess the appropriate technician certification.

The Technicians will be responsible for computer hardware troubleshooting and minor repairs. He or she will also be responsible for coordinating maintenance repairs on the system equipment in the field. These individuals would provide assistance to the Communications Specialist as necessary. The technicians must be certified, have a minimum of 2 years of experience, and possess extensive electronic troubleshooting skills.

Once the system is fully operational, it will be necessary to evaluate effectiveness and revise staffing levels as needed. It should be noted that the staffing described here is for TMC operations only. Field maintenance responsibilities for the remainder of the system are also to be considered as they are very critical to the overall effectiveness of the system. It has been found that most DOTS do not have adequate staffing levels and expertise to maintain ITS elements such as CCTV, fiber-optic communication, etc. Therefore, consideration should be made to hiring a specialty maintenance contractor to undertake overall system maintenance.

7.2.7 Training of Personnel

It has been found in similar projects that, at a minimum, the Director' s position be staffed as early as possible in the final design stage. This is beneficial for two reasons: it ensures that the overall goals and objectives are met, and gives the Director an opportunity to have extensive working knowledge of the system. Staffing would then increase as needed while the system progresses from design to construction to final implementation.

The training of the TMC personnel is directly related to the equipment and a detailed training schedule can not be formulated without that information. It can be estimated that training of engineering personnel will require approximately 1 to 2 days for each major piece of equipment. The training of maintenance personnel generally requires more time, approximately 2 additional days. Maintenance personnel must know both the operation of the equipment and its repair.

In general, the supplier of the major equipment components will include training of both operation and maintenance personnel in the cost of the installation. Therefore, the only training that the TMC would fund would be on more common equipment such as computers, and for new employees, hired after the initial installation of the major equipment. The training should be in half days with extensive hands-on training. The costs estimated for training in this item is considered to be lost work time and is estimated to be 2 weeks of the employees' time. As an average, the training at startup is estimated to be approximately $32,000 for the initial 13 employees.

7.2.8 Operations

The assumed hours of operation for the TMC is, initially, 5:00 am to 9:00 pm (16 hours per day), 5 days per week. The first shift will be from 5:00 am, when the TMC opens, to 2:00 pm. The second shift will begin at 12:00 noon and end at 9:00 pm, when the TMC closes. One Operator will monitor the system during off-hours such as nights (9:00 pm to 5:00 am) and weekends. Additional staffing will be required for special events or other periods of unusually heavy traffic.

The initial startup costs are included in the training costs as described above, with an initial check-out time for the new TMC. The startup should not require more than 2 weeks; therefore, the startup personnel costs are estimated at $32,000 for the TMC personnel.

The estimated operations and maintenance costs for the TMC are as follows:

+ Personnel for operation of the TMC consists of 13 people, including all five categories listed above, in two shifts, for an estimated yearly cost of $689,000.

+ The costs of operating the physical plant for a typical TMC, including telephone service is estimated at $183,000 per year. The yearly estimated cost for the TMC plant operation includes the telephone service because it provides service to the TMC and to the public. The cost of the telephone service is estimated at $42,000 per year and includes regular service (POTS), cellular service, and an 800 number service. The explanation of the telephone service requirements, both incoming and outgoing, is included in the "Public Interaction" section.

7.2.9 Operations and Maintenance of Field Equipment

The TMC requires several personnel and special equipment to operate and maintain the field surveillance equipment. The field personnel will be assisted by the TMC technical personnel whenever possible. It is estimated that five field personnel are required for field maintenance, a foreman, two field technicians, and two field electronic technicians. The estimated yearly cost for these personnel is $271,000.

The yearly cost of the required field equipment includes both regular and high bucket trucks to provide services to the CCTV surveillance cameras. The yearly operating cost for electric power to the field equipment is included in the spread sheet concerning the cost of the field surveillance equipment, because the cost is dependent upon the number of pieces of surveillance equipment installed along the roadway. The operating cost for the maintenance equipment included in this item covers the initial purchase of the equipment and a depreciation based upon a specific life of each piece of equipment. The yearly estimated cost for the field maintenance equipment is $43,275.

7.3 COST SPREADSHEET

The purpose of the cost spreadsheet is to serve as a tool for estimating the Corridor-wide surveillance system costs. The cost inputs to this tool are based on the experience of the Study Team on similar projects. The data on the quantity of the cost estimates are a combination of the Team' s experience, the developed conceptual design of the Corridor-wide surveillance system, and the assumptions made for system elements that are uncertain at this time (e.g., the future of TMCs in the Corridor). Given that this SR/T Project is the initial phase of the Corridor-wide surveillance system development, the input data to and the assumptions made in this cost spreadsheet are expected to be changed and/or modified as the development activities progress.

The cost spreadsheet prepared for this report contains five sections. The first section, Surveillance Element Cost Estimate, is the listing of the installation cost for all elements of the surveillance and incident detection system. This spreadsheet lists the elements on the left side of the spreadsheet in the standard format using three columns as follows:

+ Item Description.

+ Units.

+ Unit Cost.

The right side of the spreadsheet uses four paired columns to list the four types of roadways. These typical roadways are as follows:

+ Urban Freeway.

+ Rural Freeway.

+ Urban Arterial.

+ Rural Arterial.

Each of these paired columns show firstly the number of elements and then the associated total item cost for each item in a typical length of roadway. As stated previously, the typical length was chosen to be 10 miles. The bottom of these four columns is totaled to display the total installation cost for a typical section of each type of roadway. The full description of each of these roadway types is included in the following section under the heading of “Quantity Estimate.”

The second spreadsheet, Traffic Management Center, lists the installation costs for a typical TMC. The installation costs are listed in the normal format of:

+ Elements (description).

+ Unit Price.

+ Quantity.

+ Total.

The third spreadsheet is the maintenance and operations costs for the field components. This spreadsheet, entitled Field Operation Cost Estimate: Operation and Maintenance, lists the personnel and equipment required for operating and maintaining the entire Corridor. This spreadsheet also tabulates the cost of electrical power for the field equipment, and the cost of operating the aerial surveillance system (excluding flight personnel due to the lack of information). Under the aerial surveillance item in this spreadsheet, the user can select the leased cost option by entering a number of hours per day. A non-zero number under the hours column in the leased option line will be seen by the spreadsheet and the cost for aircraft purchase, on page three of the Surveillance Element Cost Estimate, will be set to zero.

The fourth spreadsheet, entitled TMC Operation Cost Estimate: Operation and Maintenance, lists the operating costs for the TMC.

The fifth spreadsheet, entitled I-95 Urban / Rural Roadways, includes the listing of all roadway sections within the corridor. These roadway sections are listed by state and agency within the state. Each roadway section has a mileage listed for the each of the four types of roadway. The road mileage data was based on the information contained in the Task 1 Report of Project 1 (IEN) and the survey conducted by this project. The majority of the roadways included in the analysis are either urban or rural freeways. Following the roadway listing for each agency, a TMC is listed for that agency. The information available at this time was insufficient to evaluate the effectiveness of any existing TMC facilities: therefore, each agency was assigned the cost of a new TMC. The costs associated with the TMC are installation of the hardware and software required for operation.

To use the spreadsheet, one must enter the type and number of detectors and surveillance elements for a typical 10-mile length of each type of roadway. This information is entered in the first spreadsheet. The initial numbers in this section are the typical or default values for each type as detailed in this report. The spreadsheet then computes the cost for each roadway section. To change the specific mileage of any roadway, the changes must be made in the appropriate spreadsheet. The TMC costs are likewise altered. If no TMC is required for a specific agency, the one (1) is changed to a zero (0) in the appropriate spreadsheet.

7.4 PRELIMINARY SYSTEM COST ESTIMATE

7.4.1 Quantity Estimate

To estimate the quantity of surveillance equipment needed, an estimate of the total mileage of the Corridor-designated roads was made. The estimated mileage was based on the available information provided in the Task 1 Report of Project #l (IEN) and the system inventory results of this Project. The road mileage was further broken down into urban and rural, and freeways and arterials based upon the population density, on a County basis as derived from the 1990 census data. This information was further refined by a review of the traffic volumes usually encountered on each roadway type. Those roadways displaying the traffic characteristics of an urban roadway were considered as an urban roadway regardless of the roadways actual location. Figure 7-1 shows the urban and rural road designations used in this system cost estimate.

For each roadway type, a typical section was used to determine the quantity of surveillance equipment needed. This quantity was then used to compute the total surveillance equipment and cost for the Corridor using the estimated total road mileage for each defined roadway type. The typical roadway sections used for the cost analysis are detailed in Chapter 6 of this report. They are summarized briefly below.

<u>Definition of a Typical Section</u>

The discussion of surveillance technologies in paragraph 7.1 has indicated that there are a variety of sensor products that may be used in the Corridor-wide surveillance system. Some of these products are more promising than others, with a wide spectrum of prices. To develop a typical surveillance section for the I-95 Corridor, all technologies had to be considered based on their performance and cost. Due to this diversity, there is not a clear-cut optimal solution for a typical surveillance section of a roadway; therefore, therefore two different scenarios are presented for the typical urban section: baseline and comprehensive. Technical requirements of a typical rural roadway section are not as complex as those of an urban section, and only one scenario is presented for the typical rural section.

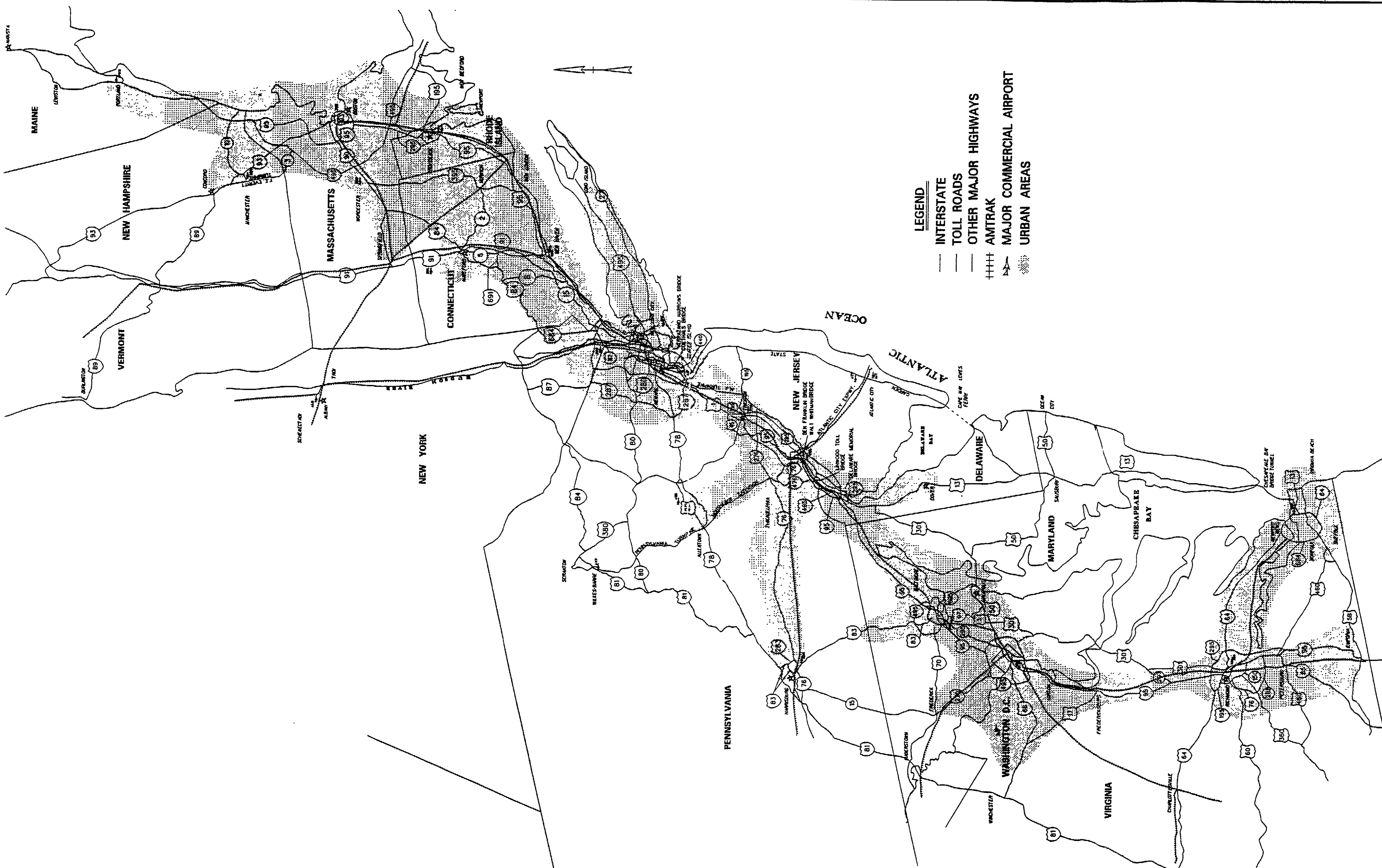

Figure 7-1. Estimated Urban/Rural Road Designations

The first scenario for a typical urban section is based on a minimal approach, where the main goal was to minimize the surveillance system cost and to provide only basic information for the system' s operation. This provides a baseline for the cost estimate. In the second scenario, the system cost was much less emphasized than the system performance.

To minimize system cost, for either approach, the tendency was to group as many units as possible into one location. For example, a CCTV camera should be placed on the same post with a side-mounted vehicle detector whenever it is possible. At some locations, placing vehicle detectors, AVI, WIM, and weather station together can significantly reduce the costs for enclosures, posts, communications, and power supply.

The number of on-ramps and off-ramps as well as the number of bridges are an influential factor for the cost estimate of a typical surveillance section. Therefore, to provide a basis for these estimates, the urban and rural parts of I-80 were used to determine the average number of major interchanges, ramps and bridges. It is assumed that a typical section has a length of 10 miles. A typical 10-mile urban section has on average twelve bridges, three major interchanges, and 26 ramps. The rural section has about six bridges and two major interchanges per 10 miles.

Typical Urban Freeway Section - Baseline

For the baseline approach, a 10-mile typical section would have 30 side-mounted radar detectors and, every 2 miles, two sets of VVDS (one for each direction for a total of ten sets per 10 miles). Since it is estimated that a typical urban section has three major interchanges, three sets of AVI, for each direction, would be desirable. In addition, one CCTV camera would cover each major interchange. Six major off-ramps would need six radar detectors. Although loop detectors seem to be the most inexpensive construction investment for ramp metering, a comparison of initial and 20-year operational costs has shown VVDS to be advantageous. Therefore, six VVDS units are assumed to be used for ramp metering of major interchange on-ramps, in addition to six ramp metering sets.

Two road sensors every 3 miles would be necessary for detection of road conditions. Due to road sensor spacing, three Remote Processing Units are necessary. One big weather station tower with sensors for precipitation, air temperature and relative humidity, and wind speed and direction is assumed for the cost estimation.

WIM stations with integrated AVI and vehicle detection are assumed to be positioned every 20 miles. The WIM should be strategically located to minimize the number of AVI and vehicle detection stations.

Typical Urban Freeway Section - Comprehensive Approach

There are only a few differences between the comprehensive and baseline approaches, but these differences significantly affect system performance and cost. The comprehensive approach would have a CCTV camera every 2 miles and together with VVDS would provide total video coverage of the roadway. Instead of placing AVI on a main roadway section, AVI would cover each ramp. Assuming that the main section has two lanes per direction, and that all ramps are single-lane ramps, this design would have 26 lanes to cover instead of 12 lanes for the previous design. The WIM system with an AVC system is assumed to be placed every 10 miles. Communications for the typical urban section contains a multi-duct system with three 48-fiber-optic cables and one spare. The first 48-fiber cable is designed for long distance transmission, the second is for distribution, and the third is for local communications. Total communication cost including conduit, fiber-optic cable, termination cable, junction boxes, and power supply for a half-mile section is estimated at $111,000.

Typical Rural Freeway Section

The typical rural section has far less freeway access points. It is assumed that a 10-mile section has two major interchanges. It is also assumed that one of these major interchanges has a high incident potential. That interchange is assumed to be covered by automated incident detection using VVDS. Ten VVDS cameras would be located on five locations, with spacing of a half mile, to cover a 1-mile upstream and 1-mile downstream section adjacent to the interchange. In addition, eight radar detectors would be enough to cover ramps of a full clover-leaf interchange. The second major interchange requires four side-mounted radar detectors to monitor mainline traffic and eight detectors to monitor ramps. To reduce communication cost, the WIM systems would be installed in the proximity of major ramps and located every 20 miles. Each major interchange would have at least two road sensors with an RPU and one set of precipitation, air temperature and relative humidity, and wind speed and direction sensors for a 10-mile typical section. Call-boxes would be installed on both sides of the freeway with spacing between them of 3 miles.

Total communication cost for a half-mile section in the proximity of major interchanges would be in the same range as that for the urban section. Unless nearby fiber-optic service is available, the communication with local TMC would be provided by leased lines or by a microwave link.

Typical Urban and Rural Arterial Section

The cost associated with the surveillance of urban and rural arterial sections is most influenced by number of intersections. As derived from the Highway Capacity Manual, a typical urban 10-mile long section has 20 signalized intersections and a typical rural 10-mile long section has five signalized intersections. In addition to the VVDS required for intersection surveillance, two VVDS per intersection, would be needed to monitor mid-block traffic conditions. Rural sections would have one call-box every 3 miles, but urban sections would not require any call-boxes.

7.4.2 Cost Summary

The spreadsheets shown in Appendix J include a full breakdown for the baseline scenario. The other five scenarios detailed below have Surveillance Element Cost Estimate spreadsheets to permit the comparison of the separate field elements in each scenario.

These costs are average costs that have been approximated from previous contracts and from vendor information. If there was a difference in cost information between actual contract (bid) costs and vendor information, the actual costs were used. The costs were also standardized for the entire Corridor as much as possible. Because of these general conditions, different agencies and authorities within the Corridor would probably disagree with some of the cost items. Their disagreement may be based upon their experience with similar ‘ items within their jurisdictional areas, and the use of different field or office items. It is intended for these differences to be identified and addressed, and that the spreadsheet should be designed with a capability to help resolve such differences to improve the cost database.

The unit costs of the items attempted to be all inclusive while not being overly detailed. Therefore, in some cases, several items were combined into a single lump sum (or “each”) cost item. Two examples of this are the workstations in the TMC and the CCTV installations. The workstations include computers with several special internal components and monitors. The CCTV installations include more components such as camera assemblies and modems, but does not call out specific details such as the small field cabinet that is usually installed on the camera support pole. The estimated cost of these two items include all the required components, but do not list each component separately. The user can alter the unit cost of any component, and the number of units used for any selected roadway type by entering the altered numbers into the "Unit Price" for the component or "Number of Units" boxes for the roadway.

Some items, such as the Weigh-In-Motion installation, include line items for several different types of installations, such as piezo WIM system, one-bending plate, two-bending plates, and load-cell system. The selected WIM technology that was used in the cost spreadsheet was the last type (i.e., load cell), but the other types are presented and can be substituted. To change from one type of system to another, the user simply enters the number of installations of the preferred unit in the correct box, under "Number of Units" for the selected type of roadway.

The routes selected for this study, and the number of miles of urban and rural, and freeway and arterial were computed as described earlier in the Quantity Estimate section. The listing of roads may be modified or added to the cost spreadsheet, but require a working knowledge of the spreadsheet logic. Therefore, it is recommended that any changes required in this area should be performed carefully to ensure that all components are correctly transferred and computed. The cost of the TMCs are not included in these scenarios because several of the agencies involved in the Corridor may have existing TMC facilities.

Several scenarios have been computed from the cost spreadsheet, and are included in this paper. Those scenarios are as follows:

+ Baseline, This scenario has sufficient sensors on all roadways to provide usable data to the TMC, but the number and location of the sensors have been optimized for lower system cost.

+ Scenario 1. This scenario is the same as the baseline scenario, but with additional implementation of CCTV and AVI systems. This enables full surveillance and incident detection of the roadways. The system performance is optimized, while the system cost is a secondary concern. The differences between this scenario and the baseline scenario are confined to the Urban Freeway computations.

+ Scenario 2. This scenario is the same as the baseline implementation but the ramp control (ramp metering) element is removed to reduce cost.

+ Scenario 3. This scenario is the same as the baseline but the ramp control (ramp metering) and roadway condition sensor elements are removed.

+ Scenario 4. This scenario is the same as the baseline but the ramp control (ramp metering), roadway condition sensor, and WIM elements are removed.

+ Scenario 5. This scenario has only incident detection systems, including vehicle detectors, CCTV surveillance, call-boxes, and surveillance aircraft.

The approximate installation costs for each of these scenarios, excluding TMC costs, rounded to the nearest million, are listed in Table 7-8.

Table 7-8. Estimated System Implementation Cost Under Various Scenarios

Scenario	Description	Cost, million $
Baseline	< Complete roadway coverage < Ramp Control < Road/surface condition monitoring < WIM sensing < Air quality and weather monitoring < Aerial Surveillance < Minimal use of CCTV and AVI System	2,171
1	Same as Baseline but with full implementation of CCTV and AVI systems	2,299
2	Same as Baseline but without ramp control	2,022
3	Same as Baseline but without ramp control and roadway condition sensors	1,998
4	Same as Baseline but without ramp control, roadway condition sensors, and WIM	1,976
5	Same as Baseline but without ramp control, roadway condition sensors, WIM, and air quality/weather sensors	1,957

The costs for the TMC installations were considered to be the same regardless of the location because there was insufficient information concerning the capabilities of the existing TMCs. These costs can also be altered, and should be carefully considered by each agency. The estimated cost for the installation of the hardware and software for a TMC, not including any incident detection algorithms, is approximately $3,125,000.

The maintenance and operations costs were also computed. Two major components of the maintenance and operation costs are the TMC personnel and physical plant costs, and the field personnel and equipment required for service of the roadside equipment. These costs will experience only minor fluctuations with different implementation scenarios, and for this estimate, the minor fluctuations will be discarded as less than the possible deviation in the total cost. The possible changes in maintenance and operation costs for the Corridor are minor because the same TMC operation and field crew size can operate and service a wide range of field components. The estimated maintenance and operations cost for field hardware in the Corridor is approximately $1,350,000 including personnel, service equipment, and electric power for the roadside field equipment. The estimated operations and maintenance cost for a year of aerial surveillance is approximately $1,095,000 (excluding personnel and insurance cost, because this information is not available due to the emerging technology involved). An alternative cost for the aerial surveillance element is to use the lease option: thereby, increasing the yearly cost to approximately $4,380,000, but eliminating the initial purchase cost, and all personnel and insurance costs. The estimated operations and maintenance cost of a TMC is approximately $872,000.

7.5 SUMMARY

In this Chapter, the unit cost elements for the surveillance system were developed and the preliminary cost estimates for installation, operations and maintenance computed. The resultant cost estimates indicate that a Corridor-wide surveillance system may be expensive to install and maintain, but the alternative to the installation of such a system is the continuing increase in congestion on the roadway systems. However, the costs to the existing system and to the public resulting from increased congestion is high in real dollars and in perceived costs of lost time. The costs detailed herein are average estimates that have been standardized for the entire Corridor. The spreadsheet was formulated so that the installation, and operations and maintenance costs can be altered; new and revised costs can be inserted. Thus, inputs and comments are sought from government agencies and authorities to improve the accuracy of the cost data elements so that a useful cost database is available for use by all Coalition members.

The type of detector used in the system has been standardized in this analysis, but a specific agency may require or prefer a different type of unit. This preference could be based on cost or experience with specific types of detectors; regardless, the cost table can and should be altered to reflect those changes when an agency runs the software for its own use.

Likewise, the need to install a TMC for the surveillance system may be questioned by an agency if it feels that an existing TMC would be adequate. Special consideration should be exercised before the TMC costs are removed from the estimate because the additional roadway being placed under surveillance may require additional equipment and personnel.